2006-81: A NEW UNDERGRADUATE COURSE IN ELECTROMECHANICAL SYSTEMS FOR INDUSTRIAL ENGINEERING TECHNOLOGY

Ranjeet Agarwala, East Carolina University

Mr. Agarwala serves as a lecturer in the department of Technology Systems at East Carolina University. His research interests are in the area of Adaptive Control, Neuro –fuzzy systems, Internet based Teleoperational systems and Robotics &Automation.

Tarek Abdel-Salam, East Carolina University

TAREK ABDEL-SALAM received his Ph.D. in mechanical engineering from Old Dominion University. He is currently an assistant professor of engineering in the Department of Technology Systems at East Carolina University. His research interests include educational effectiveness in engineering education, energy management and thermal / fluid systems.

Craig Sanders, East Caroilina University

Dr. Sanders is currently an Assistant Professor in the Department of Technology Systems at East Carolina University.

A New Undergraduate Course in Electromechanical Systems for Industrial Engineering Technology

Abstract

There is an increasing need in engineering and technology educational practices to include interdisciplinary components. This paper describes key curriculum activities in a new electromechanical systems course developed for Industrial Engineering Technology students at East Carolina University (ECU). Details of the course components are provided in the paper including full descriptions of both lecture and laboratory components (hardware and software). The assessment of the course is also presented in the paper through student surveys, portfolio reviews, grade distribution and Accreditation Board for Engineering and Technology (ABET) outcomes. Assessment results were satisfactory and provided useful pointers for class and group work definitions to be attained by future engineering technology students. Overall, this course will foster active learning through synergistic, integrated mechanical and electrical educational components consistent with the ABET learning outcomes.

Introduction

Due to the accelerated growth and use of electronics, computers and information technology, a gap has emerged between traditional engineering/technology education and the skills expected of students entering the job market. A deluge of computers, sensors, microcontrollers, and actuators have penetrated the present day society and have influenced our daily lives profoundly. Therefore, there is a need for technology graduates who can use combinations of electrical and mechanical concepts in design, installation, and service of products and production systems.[1]

One of the goals of the Department of Technology Systems at East Carolina University is to support the economic development of eastern North Carolina by providing professionals to meet the general engineering and technology needs of the region's private and public sectors. The department has six degree programs including Engineering and Industrial Engineering Technology. Both programs emphasize the application of engineering and technology theories as applied to real world problems. ECU students are engaged in hands-on activities beginning the first semester of their freshman year as opposed to more traditional engineering programs that wait for several semesters or years to expose students to engineering and design courses. During the last three years, there have been tremendous efforts in the departments to modify and update the curricula of all the department's programs to include hands-on lab experience.

When it comes to designing an electromechanical curriculum or course, [2-4] it is not clear where the emphasis should lie. Electromechanical systems mean different things to different people. It can be the philosophy of design which brings together many disciplines in a concurrent technology or engineering environment.[5] It can also be a philosophy of complete system modeling and simulation.[6] If all of the arguments are factored in, then electromechanical education should be about relevant interdisciplinary technical knowledge acquired through active learning and team working skills.

The Electromechanical Systems (ITEC 2090/2091) course is intended for sophomore or junior students with a background in electricity and electronics fundamentals. The course consists of three semester hours with two hours of lecture and one of hour lab per week. ITEC 2090 includes the fundamentals of mechanical systems, programmable controllers as well as practical applications of interfacing mechanical, electrical, pneumatic and hydraulic systems. ITEC 2091 is a team-oriented and active-learning based laboratory component. Students are given general instructions and guidelines to assemble and conduct experiments through self and group learning.

The New Electromechanical Course Structure

This course is designed to help students apply technology to meet business and customer goals. The objectives of this course are to give students an overview and experience in electromechanical systems, an opportunity for hands-on laboratory work and to encourage students interested in majoring in technology-related professions.

ITEC 2090/2091 is required for all students graduating with degrees in Industrial Engineering Technology (see appendix 1), Design and Distribution. The course is described as the design, analysis and control of electromechanical systems achieved by interfacing mechanical, electrical, pneumatic and hydraulic components with programmable logic controllers (PLCs). The prerequisite to the course is Electricity (ITEC 2054). In ITEC 2054, students study electronic components, circuits and industrial control systems. Figure 1 shows the course content [2] and Table 1 provides the details of active learning components along with the hardware and software used to achieve it.

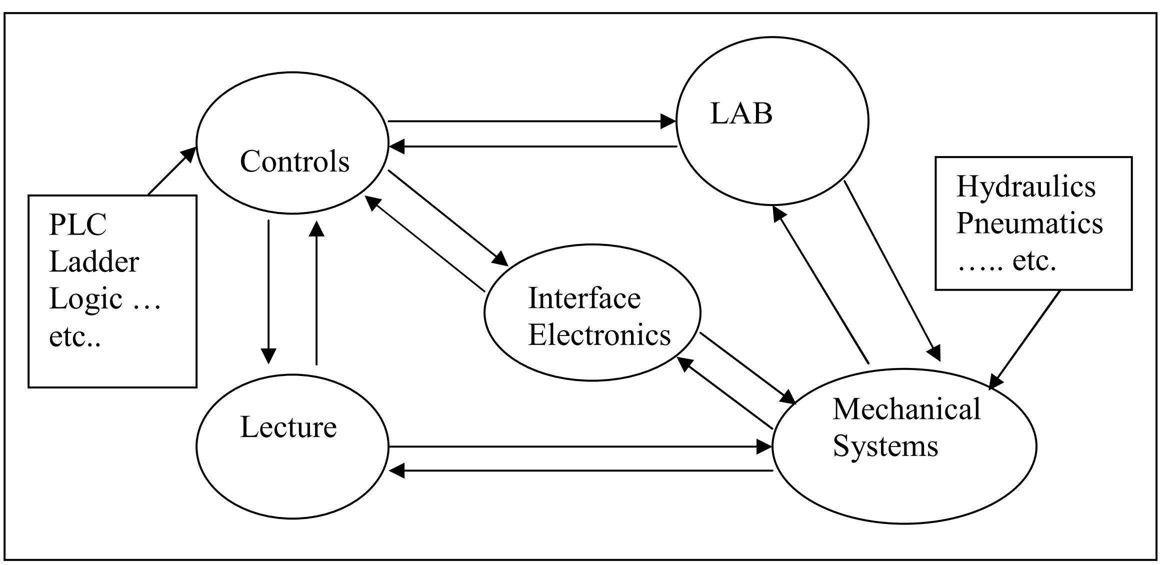

Figure 1. Course content

Course component	Lab Hardware/Software	Student Learning
Mechanical	Mechanical Systems[9] Hardware: Servos Motors	Students learn basic principles of mechanical systems, component operation, system design, component installation and adjustment. Components include: fractional horsepower and heavy duty style components, three types of bushings, seven types of couplings, single and multiple belt drives, single and multiple chain drives, silent chains, synchronous and HTD belt drives, spur gear drives, manual lubrication, plain bearings, roller bearings, seals, and gearboxes
	Pneumatics and Hydraulics [8] Hardware: Pneumatic components Hydraulic components Electro-pneumatics Electro-Hydraulics Software: Fluid-Sim	Students learn pneumatics and hydraulics through principles and uses of compressed air, circuit logic, sequencing and control functions, using circuit design and hands-on construction. Students learn pneumatic components and their uses in industrial applications. Circuits are designed using cylinders and directional control valves, as well as logic, timing, sequencing and emergency stop functions.
Electronics Controls & Interfaces	Controllers and Interfaces. [9,10] Hardware: Amatrol's Allen Bradley SLC500-based programmable controller	Students learn basic principles of ladder logic, basic PLC operation, PLC programming using RS Logix software, program entry, Program start/stop, basic PLC program design, IO interfacing, and PLC applications. Control systems are designed using cylinders and directional control valves, motors as well as logic, timing, sequencing and emergency stop functions, programmed in a PLC software.

Table 1: Course and lab components (hardware and software) and their relationships to student learning

The semester is covered over a time period of fourteen academic weeks. The lecture is broken into three parts. The first part deals with the principles and applications of mechanical systems followed by pneumatics and hydraulics systems. The last part deals with PLCs and integration of mechanical, pneumatics and electrical components. Weekly lectures are supported by lab work wherein students work on hands-on lab exercises in teams of four.

The course objectives encompassed

- Basics of several types of power transmission, including levers, bell cranks, pulleys, gears, belts, chains, clutches, couplings, bearings, linkages, rotary mechanisms, actuators, accumulators, compressors, controls, transformers, motors, generators, servomotors, and induction.

- Different type/categories of PLCs, basic Boolean functions, designing, developing, interpreting ladder diagrams and designing discrete-state process control systems, writing, debugging, testing and running programs on PLCs, Interfacing, programming, collecting and analyzing data from PLCs.

Student Experience Samples

Figure 2 and 3 presents sample setups of electromechanical systems [8, 9] lab. Figure 2 shows students engaged in constructing and designing an elctropneumatic system for a shorting device. In this setup, the piston of a single-acting cylinder pushes the part off the conveyor belt when a pushbutton switch is pressed. When the pushbutton is released, the piston rod returns to the retracted end position. The students realized this experiment using standalone pneumatic and electropneumatic components.

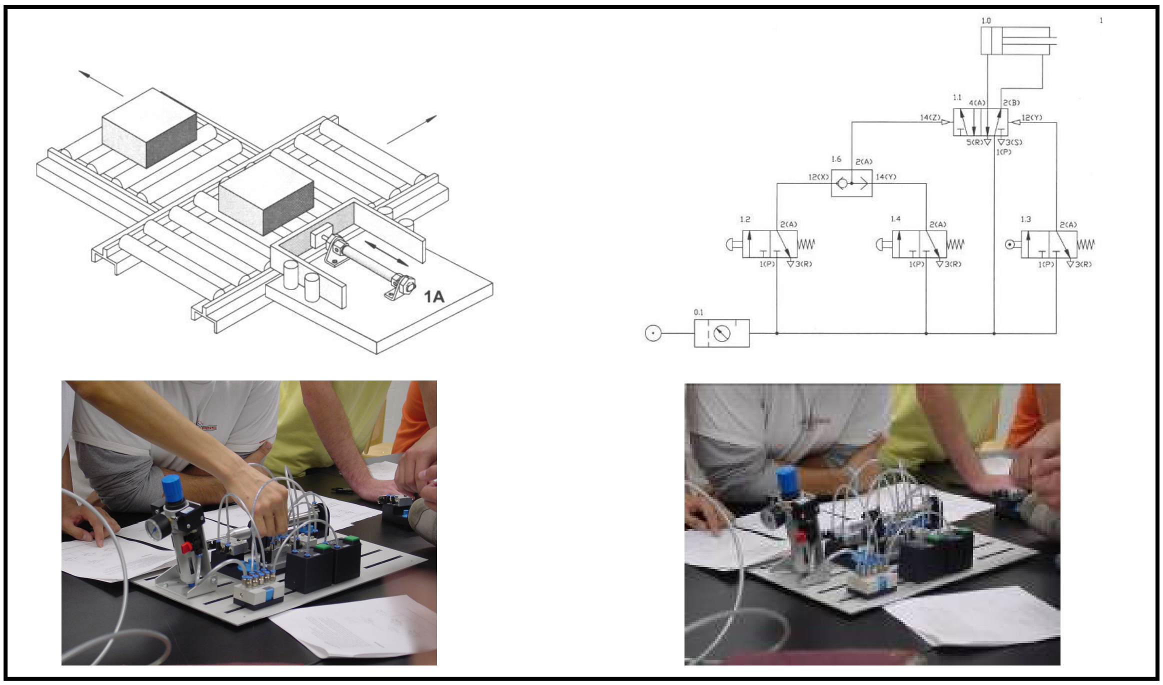

Figure 2: Students engaged in designing electromechanical systems

In a different experimental setup, as presented in Figure 3, the students were required to simulate a simple drilling operation. The drill press would only operate if there was a part present and the operator had one hand on each of the start switches. This experiment was realized using a ladder logic diagram as presented in the same figure.

Here the students were required to model sensor inputs PB1 and PB2 and part sensor as input switches 5, 6, 7(digitally 4, 5, and 6) . The output of the ladder logic connected to the motor was at output 1 (digitally 0) which was energized when the states of all inputs were 1.

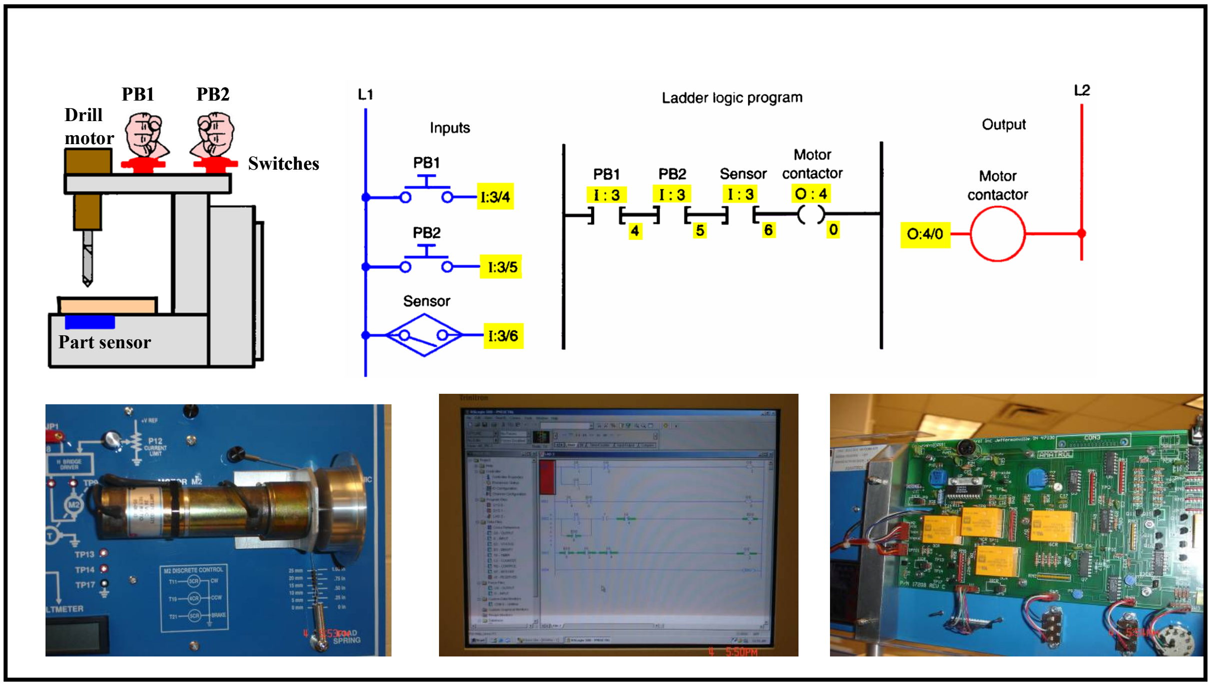

Figure 3: Experimental setup of a PLC motor control using Ladder logic

The control of the motor application was realized using ladder logic program written in Rx Logic supplied by Rockwell Automation. The PLCs were also networked for remote operation through local area network (LAN) and wide area network (WAN).

Course Assessment

The students were surveyed in the class with respect to their learning achievements in a collaborative team environment. The survey results are presented in Table 2. Figure 4 graphically presents the mean and standard deviation of student achievements results in relation to each survey question. The mean value of each survey item indicated the average score of the student evaluation while the standard deviation indicated the deviation from the mean and the frequency of such deviation. Scale of 1 indicated that the students needed to improve on a particular skill while a scale of 5 indicated that the students did well. It was observed that the students did well in the areas of science, mathematics, listening skills, peer evaluation and coaching skills. These skills go a long way to enhance students' ability to identify, assimilate and integrate technology-related theories and fundamentals. This results in the acquisition of vital learning skills through coherent sets of learning experiences enhanced by reinforcement and refinement over a wide range of applications.

The science and mathematics skills helped students to grasp the content of the course while listening skills further enhanced it. Students assessed the strengths and weaknesses of each other through peer evaluation, and the coaching skills helped them to remedy their weaknesses.

Area of Student Improvement	Mean	Standard Deviation
1. Basics science and mathematics	4.33	0.82
2. Listening skills	4.12	0.75
3. Skills to evaluate the performance of other team members	4.30	1.03
4. Skills to provide constructive feedback to team members	3.17	0.75
5. Skills to receive feedback from team members	4.00	0.89
6. Coaching skills	4.17	0.71
7. Negotiating skills	3.83	0.98
8. Skills to communicate with other team members	4.00	0.89
9. Skills to manage a team project	4.00	1.26
10. Skills to be a team leader	3.83	0.98
11. Skills to adapt to differences in team members' work styles.	3.17	1.17
12. Skills to adapt to different cultural norms of team members	3.26	0.47

Table 2: Student perspectives of team learning achievement

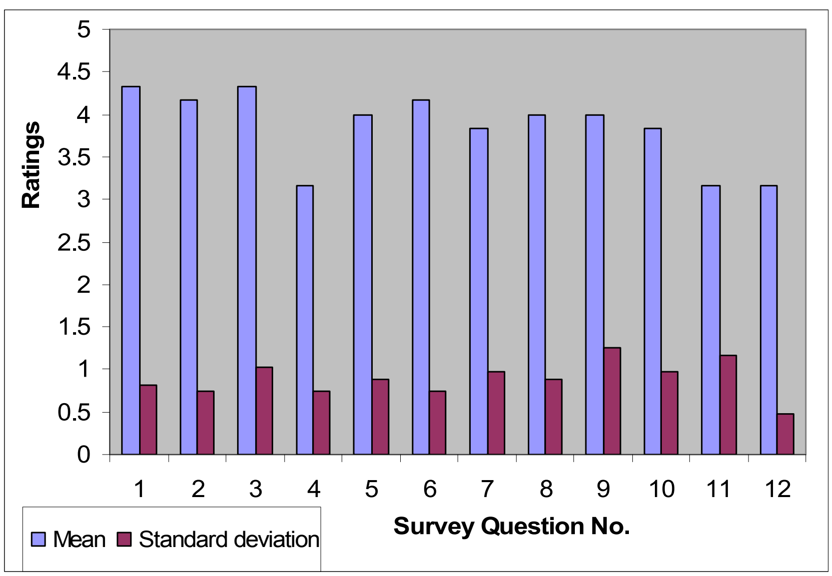

Figure 4: Graphical results of student survey

The students performed acceptably in the areas of team feedback, team communication, project management, negotiating skills and leadership. These skills are extremely useful for the success of a team and its assignments. These skills helped students distribute their workload, reinforce individual capabilities, create participation and involvement, make better decisions and generate diversity of ideas.

From the survey results, it was also evident that the students required improvement in the areas of feedback adaptation skills. Feedback is the key to effective adaptation and change. This is especially critical because of the dynamic nature of today's diverse environments. Immediate feedback gives individuals and teams the collaborative change skills that empower them to monitor their own progress towards best practices and continual learning. With this evolving knowledge, individuals and teams successfully re-align their own working relationships in response to changes in their team members' cultural norms and work styles.

The performances of every student in the class were assessed, as shown in Table 3. Figure 5 presents the grade distribution of the class. It was observed that 21% of

Assessment	
Exams	50 %
Quizzes	10%
Lab Assignments	30 %
Class Attendance	10%

Table 3: Student (Course) assessment

the students obtained "A", 25% "B", 42% "C" , 8% percent "D" and 4 percent obtained a letter grade of "F". The grade distribution indicated good performance of the class on the whole.

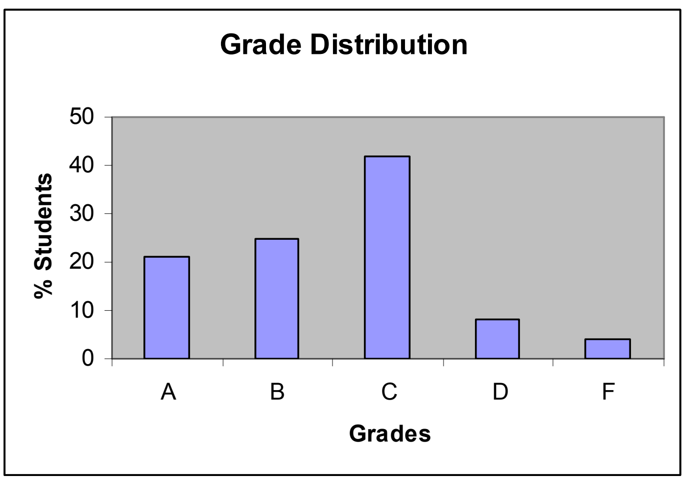

Figure 5: Student (Course) assessment

Structure of Lab Report

Each student group was required to submit reports for experiments in two forms: a data log book and a formal report. Each student was responsible for maintaining a data log book and the group was responsible for the formal reports. Each experiment was written in data ledgers (composition book) kept by each individual in the lab. The logbook was filled out as the experiment was conducted. Each experiment was reported in the following order;

Title of experiment
Objective of experiment
Date performed
Members in group
Projected procedure
Equipment used
Data and tables
Observations made during experiments

The formal reports were broken down into four sections. Each person in the group was responsible for different sections of different reports. The sections that were grouped together were as follows.

Section 1: Summary
Section 2: Theory, governing principles and standards
Section 3: Equipment and data
Section 4: Analysis, discussion and procedure/method

The reports were required to have a title page, bibliography and references. The order in which information was presented was as follows:

Summary: A brief statement of the objective of experiment and findings in terms of results.

Introduction and theory: The underlying principle, standards and methods used as guidelines for the experiment.

Procedure/method: The students were required to state the procedure used by the group. They were also required to reference equipment list and indicate how the equipment was used.

Equipment: The students were required to list all equipments including maker, model number, ranges, and neat sketch of apparatus set up showing relation and use of each piece of equipment.

Conclusion: The students were required to include a brief discussion of the conclusion they derived.

Accreditation Compliance

Accreditation is used to assure quality in educational institutions and programs. It requires an educational institution or program to meet certain defined standards or criteria. Accreditation verifies that an institution or program meets the criteria, ensuring a quality educational experience. Accreditation helps students in choosing an educational program, parents seeking assurance of quality education, institutions seeking improvement of education provided by their programs and employers seeking recruitment of well-prepared graduates. It also helps state registration, licensure and certification boards to screen applicants for entry into professional practice and industries to voice their educational needs. ABET is the standard and the most widely-accepted accreditation agency in the field of engineering and technology education.

For all these reasons, the Industrial Engineering Technology program at ECU seeks to be accredited by the Technology Accreditation commission (TAC) of ABET. To fulfill the accreditation requirements of the program, every new course need to be assessed against the published engineering technology specific ABET criteria. The course level assessment of the electromechanical systems with respect to ABET criteria is provided in Table 4. Here, “K” indicates knowledge, "A” indicates application and “M” indicates mastery of course competencies attained by students with respect to ABET Criteria 3. [11]

ABET Program Outcomes (a-k): Criteria 3	K	A	M
a) An appropriate mastery of the knowledge, techniques, skills and modern tools		X	
b) An ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering and technology.		X	
c) An ability to conduct, analyze and interpret experiments and apply experimental results to improve processes.			X
d) An ability to apply creativity in the design of systems, components or processes.		X	
e) An ability to function effectively on teams.		X	
f) An ability to identify, analyze & solve technical problems.		X	
g) An ability to communicate effectively.	X		
h) A recognition of the need for, and an ability to engage in lifelong learning.	X		
i) An ability to understand professional, ethical and social responsibilities.	X		
j) A respect for diversity & knowledge of contemporary professional, societal & global issues.	X		
k) A commitment to quality, timeliness, & continuous improvement.	X		

Table 4: Course level assessment with respect to ABET Criteria 3

The course level assessment indicated that the new course contributed well in addressing the ABET outcomes needs of the program. It was observed that the course fulfilled five program outcomes at the level of knowledge, five at the level of application and one at the level of mastery.

Discussion

Student assessment results were satisfactory and provided useful pointers for class and group work definitions to be attained by future engineering technology students. Student assessment results indicated the need for improvement in team members adapting to different cultural norms and work styles within a team. It also indicated a need for individual team members to provide constructive feedback to fellow team members. Course level assessment indicated satisfactory fulfillment of ABET program outcomes towards the accreditation needs of the overall program. The input from students, faculty and industrial advisory board were integrated to provide future direction to the course, as presented in Figure 6. The opinion and consensus of the various program constituents pointed towards the inclusion of distance delivery capabilities in the course. To accommodate this, various components of the course were devised as standalone modules woven together in a distributed environment. Web extensions to the laboratory components were contemplated wherein students will build and execute ladder logic and various control algorithms remotely. This will help sustain and strengthen the enrollment of the program and would enable the department to offer this course remotely.

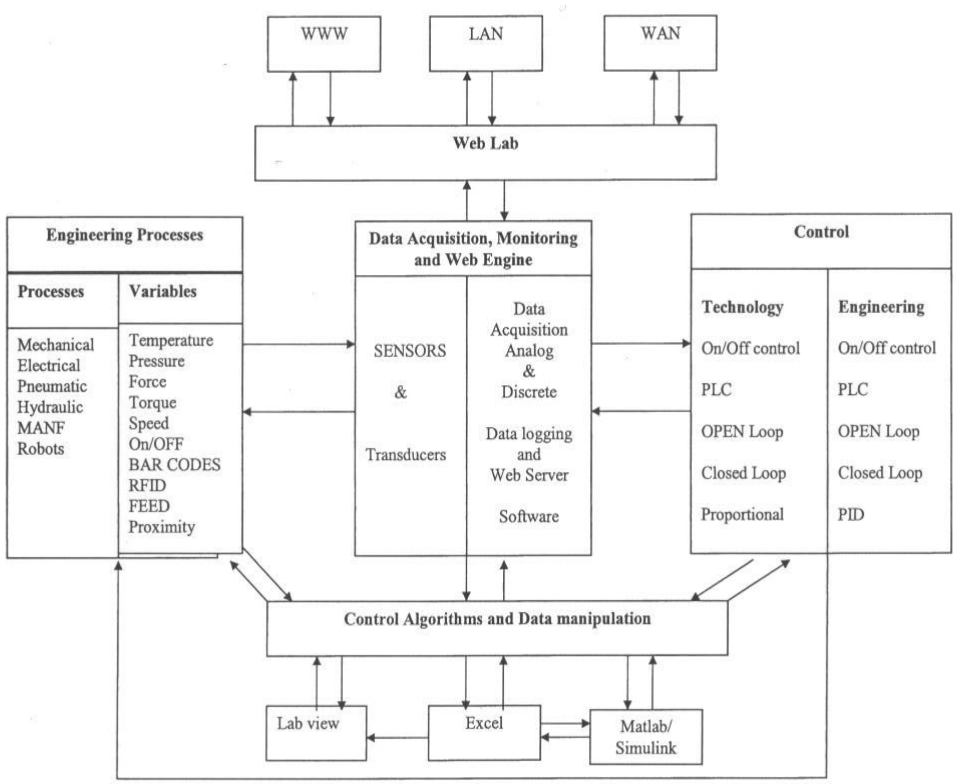

Figure 6: Future roadmap of the course

Conclusion

Many universities have started offering similar courses to undergraduate students. Such courses cut across discipline boundaries and combine theory and hands-on experiments to greatly benefit the undergraduate students and faculty. These courses stimulate the curriculum towards the forefront of engineering education and directly answer the training and education challenges of the 3rd millennium. The Department of Technology Systems at East Carolina University has embarked on this mission to enhance the education of industrial engineering technology students. The department faculty at ECU are working together to take this course into higher levels of integration through experiments which emulate real world scenarios. Hence, our approach will help expand students' understanding of the synergistic relationship of electrical and mechanical components from both mental analysis and hands-on viewpoints. This paper provides useful pointers to programs in planning, structuring, evaluating and assessing offerings of such new courses within their departments.

References

[1] Meek, S., Field, S., Devasia, S., "Mechatronics Education in the Department of Mechanical Engineering at the University of Utah," *Mechatronics*, Elsevier, 13:1-11, 2002.

[2] Giurgiutiu, V., Lyons, J., Rocheleau, D., Liu, W., " Mechatronics/Microcontroller Education for Mechanical Engineering Students at the University of South Carolina," *Mechatronics*, Elsevier, 15:1025-1036, 2005.

[3] Wild P.M., Surgenor B.W., "An Innovative Mechatronics Course for a Traditional Mechanical Engineering Curriculum," American Society of Engineering Education. Session 2566

[4] Grimheden, M., and Hanson, M., "Mechatronics-The Evolution of an Academic Discipline in Engineering Education," *Mechatronics*, Elsevier, 15:179-192, 2005.

[5] Angelov, C., Melnik, R.V.N., Buur, J., "The Synergistic Integration of Mathematics, Software Engineering, and User-Centered Design: Exploring New Trends in Education," *Future Generation Computer Systems*, Elsevier, 19:1299-1307, 2003.

[6] Wright, A.B., "Planting the Seeds for a Mechatronic Curriculum at UALR," *Mechatronics*, Elsevier, 12:271-280, 2002.

[7] Hargrove, J.B., "Curriculum, Equipment and Student Project Outcomes for Mechatronics Education in the Core Mechanical Engineering Program at Kettering University," *Mechatronics*, Elsevier, 12:343-356, 2002.

[8] Internet: "www.festo.com," *Festo U.S. Learning Systems*.

[9] Internet: "www.amatrol.com," *Learning Systems for Technical Education*.

[10] Amatrol, "Mastering Programmable controllers: Lap PLC motor control Allen Bradley SLC 500," *B408 AA*

[11] Internet: "www.abet.org," *Accreditation Board for Engineering and Technology*, Technology Accreditation Commission, Engineering Technology accreditation criteria 2005-2006.

Appendix 1: Industrial Engineering Technology Program Curriculum at ECU.

Appendix 1

Industrial Engineering Technology Program Curriculum at ECU

Fall Semester			Spring Semester	
Freshman				
ENGL (English) 1100	3		ENGL (English) 1200	3
PSYC (psychology) 1000	3		HLTH (Health) 1000	2
MATH 1065: Algebra	3		MATH 1074: Trigonometry	2
Humanities /Fine Arts	3		DESN 2034, 2035: Eng. Graph. I	3, 0
ITEC 2000: Computer Applications	3		MANF 2020, 2021: Materials	3, 0
EXSS (Exercise)1000	1		ECON (Economy) 2113	3
	16			16
Sophomore				
PHYS 1250, 1251				
MATH 2119: Calculus	3, 1		PHYS 1260, 1261	3, 1
MANF (Manufacturing) 2076/77: CNC	3		DESN (Design) 3032.3033: Eng Graph II	3, 0
DESN 2036, 2037: CAD	3, 0		*ITEC 2090, 2091: Electromechanical Sys.*	3, 0
Pre-requisite: ITEC 2054, 2055: Electricity/Electronics	3, 0		Humanities/Fine Arts	2
			MATH 2283 or ITEC 3200: SPC	3, 0
	15			16
Junior				
COMM (communications) 2420				
MANF 3300: Plant Layout & Mat. Hand.	3, 0		ITEC 3300: Project Management	3
Social Science Elective	3		MANF 3020/01: CIM	3, 0
DESN 3236/37: GD&T	3		CHEM (Chemistry) 1150/51	3, 1
ITEC 3290: Tech Writing	3		ITEC 3292: Safety	3
ITEC 2080/81: Thermal & Fluid Systems	3		ITEC 4300: Quality Assurance	3
	18			16
Senior				
ITEC 4293: Supervision				
MANF 4020/21: Mfg Systems Planning	3		MANF 4200: Work Methods Analysis	3
PSYC 3241	3, 0		Humanities/Fine Arts	2
OPERATIONS RESEARCH	3		MANF 4023: Advanced Mfg. Systems	3
DYNAMIC SYSTEMS	3		ITEC 3800: Finance	3
	3		CAPSTONE COURSE	3
	15			14